DOCUMENT RESUME

ED 248 841 IR 011 290

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TITLE Computer-Based Learning and Postsecondary Education: Some Experimental Projects and a Learning Model.
PUB DATE 83
NOTE 30p.
PUB TYPE Information Analyses (070) -- Reports - Descriptive (141)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS College Students; *Computer Assisted Instruction; *Computers; Higher Education; Instructional Materials; Intermode Differences; *Learning Processes; *Media Research; *Models; Postsecondary Education; *Program Evaluation
IDENTIFIERS Computer Uses in Education; PLATO; TICCIT Computer System

ABSTRACT

This discussion of questions related to the most appropriate role for the computer in undergraduate postsecondary education begins by describing the Educational Testing Service's evaluations of two large-scale funded projects intended to stimulate the incorporation of computer assisted instruction (CAI) into undergraduate instruction--the network-oriented PLATO (Programmed Logic for Automated Teaching Operations), and TICCIT (Time-Shared Interactive, Computer-Controlled Information Television), which used a stimulus/response learning model. A summary of the evaluation results indicates that CAI should be integrated into classroom instruction rather than serve as a substitute for it; neither project saved instructor time or proved useful for poor students; and students who were initially stronger performed better. A learning model for higher education drawn from a report prepared for the Carnegie Commission by Rockart and Scott Morton is then discussed. This model provides a framework for the integration of new technologies, and is based on the stages of the learning process and the characteristics of the material to be learned. Related studies, including one by James and Chen-Lin Kulik on research on college teaching, are examined to support the model. The concluding statement suggests that extensive use of CAI will become a reality in the next decade. Sixteen references are listed. (LMM)

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ED248841

(1983)

COMPUTER-BASED LEARNING AND POSTSECONDARY EDUCATION: SOME EXPERIMENTAL PROJECTS AND A LEARNING MODEL

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Introduction

In 1967, a prestigious national committee had confidently envisioned that all college students would be computing by the early 1970s (PSAC, 1967, p. 4), although at that time, less than half of the nation's institutions of higher education employed a computer even for administrative use (Levien, 1972, p. 143). Since then, there have been several important developments, chief among them the rapid and dramatic spread of the microcomputer into schools, offices, and homes. Almost all colleges now use computers for teaching, research, and administration, and many have departments of computer science as well.

During the past 25 years, a great deal of time, effort, and money--mainly the public's money--have gone into the development of computer-supported learning. Investments at the postsecondary level have not been so substantial as at the elementary and high school levels, but the sums would, nevertheless, provide a respectable endowment for a good-sized college. Among these investments have been two large-scale government funded projects to date, intended to stimulate the incorporation of computer-based instruction into the undergraduate curriculum--at a combined cost of $14 million (Kulik et al., 1980, p. 526). Neither was commercially successful, although this was the specific intention of at least one. The assumption that computers will become an important part of undergraduate instruction is widely shared, but scepticism persists on the part of some as to its potential effectiveness with questions on the part of many as to what the computer's most appropriate role is. These questions will be addressed in this paper.

Changes in available hardware have brought these questions into prominence. The report on Computers in Higher Education prepared by the President's Science Advisory Committee in 1967 (known as the Pierce report) was accurate in its predictions about the extensive impact computers would have on colleges and universities, but did not anticipate the technology eventually involved or the time

frame (PSAC, 1967). Minicomputers were then relatively new and microcomputer use other than by hobbyists was a decade away.

The Pierce report foresaw several large, central mainframe computing facilities, perhaps on state university campuses, and advocated widespread use of these facilities by smaller colleges connected on a timesharing basis. Concerned that too many colleges did not have access to computing facilities, the committee proposed their establishment through government subsidy (ibid, p. 4).

Although the Pierce report anticipated colleges' rapid adoption of computers, it did not anticipate how this would happen. The authors' vision of large networks connected to mainframes has been replaced by the reality of many different computers, either independent or interconnected and diverse in size. This has affected how computers are being incorporated into the learning process, but some expensive and, in hindsight, inappropriate applications have been tried in the meantime. Much of the research done on computer-based education (CBE) indicates that an ineffective model has been followed for its development. The first computer-assisted instruction (CAI) projects, most of which got underway in the early 1960s, grew out of teaching machines and programmed instruction (Atkinson, 1968, p. 73). They followed a Skinnerian approach to learning, and many relied heavily on models developed for military training (Hickey, 1968). However, tutorials or rote drill and practice may well not be the most effective use of computers in the classroom learning process, particularly when costs are considered.

The first major experimental tests of computers in college instruction were instituted during the early 1970s. One of these was the PLATO system installed at five community colleges in Illinois in 1974. Another system, TICCIT, was installed at two other community colleges. PLATO was notable for its reliance on the network notion envisioned by the Pierce report; TICCIT, for its use of a stimulus/response learning model. Both were funded by the National Science Foundation and extensively evaluated by the Educational Testing Service (ETS).

In 1972, the Carnegie Commission on Higher Education sponsored publication of The Emerging Technology, edited by Roger E. Levien, the first of two reports on instructional uses of the computer in postsecondary schools. The second, published in 1975, was entitled Computers and the Learning Process in Higher Education and written by John Fralick Rockart and Michael S. Scott Morton. The most comprehensive survey of postsecondary instructional computers is, apparently, one published in 1980 by Reviews of Educational Research (Kulik and Kulik, 1980). At present there are numerous books and several periodicals available nationally that cover various aspects of instructional computing in elementary and high schools. By comparison, there seems to be a dearth of readily available recent information on instructional uses of the computer in postsecondary education.

The ETS Evaluations of PLATO and TICCIT

PLATO (Programmed Logic for Automatic Teaching Operations) was developed in the early 1960s at the University of Illinois. It is a mainframe system, in which all memory and systems programming are handled by a central computer in Champaign-Urbana. (There are now other PLATO installations around the country, but this is still the largest one.) Schools on PLATO are connected via telephone; students using the system sit at special keyboards and operate a touch-sensitive screen. PLATO facilities have 10 to 25 terminals apiece, and each student can have individual access to the complete library of programs. By 1970, the Center for Electronic Resources Laboratory (CERL) at Illinois, which had been developing the system, felt it was ready for widespread use and received National Science Foundation support to test it.

CERL had two specific goals in mind for this experiment: they wanted the system implemented cooperatively with participating schools, and the specific applications dependent on the interests and efforts of the school's instructors.

In addition, they wanted the system to be flexible and adaptable to "real world" constraints. During the development, implementation, and demonstration phases of the project, CERL worked cooperatively with an evaluation team from ETS (Murphy and Appel, 1977). The following information is taken from their report.

CERL chose a community college environment because of its interest in large enrollment, introductory courses. Basic courses in accounting, biology, chemistry, English, and mathematics were chosen. Three of the five participating schools were Chicago community colleges, one an adult basic skills center, and the last a downstate community college. CERL envisioned that PLATO would serve class-size groups of students working on the same lesson. Instead, students chose lessons individually, limiting the system to fewer terminals. Also unanticipated was the extensive use of TUTOR, the authoring system devised for writing lessons.

Whatever its limitations, PLATO affected a tremendous number of students. CERL had anticipated that only three to four hundred students would use it each year. Instead, for the two academic years 1974 to 1976, four to five thousand students per semester signed on to PLATO. They were at the terminals for times ranging from a few minutes to 20 hours, averaging from three to eight hours per semester. About 90 teachers were involved over the two years. CERL anticipated that PLATO lessons should take up about a third of regular classroom time, which the instructors also felt was appropriate. Actually, usage was much more erratic, as average time on terminals indicates.

Lesson development, or PLATO's place in the curriculum, was problematic throughout this project. CERL had been overly optimistic about the amount of time it would take to produce an adequate number of lessons, and the evaluation phase had to be delayed for a year while lessons were being written. While the system was being installed, graduate students in Champaign developed some lessons, and they were later joined by some participating instructors. Unlike the TICCIT program, which had a highly structured lesson design, there was no overall scheme for PLATO materials, and lessons were developed haphazardly.

The real world orientation that CERL insisted upon was both a virtue and a limitation. Instructors used PLATO when and how they wished, which meant that there was no way of testing specific topics covered by PLATO instruction. As community college students tend to drop out more frequently than four-year students, it was hoped that PLATO might reduce student anxiety and encourage students to remain in class. Instead, ETS found that there were no consistent effects on attrition, and no significant or consistent effects that could be explained in terms of treatment differences. ETS concluded that their data offered "relatively conclusive evidence that completion is positively related to initial ability," not to PLATO (ibid, p. 63).

ETS also looked at student achievement, and concluded that PLATO was neither helpful nor harmful. Because the lessons had not been organized to integrate with existing courses, there was no way of testing specific topics covered by PLATO instruction. Where there were achievement differences, ETS found that they were more likely due to the instructor than to PLATO. They did arrive at one significant conclusion for future development of CBE: "In those few instances [where there were noticeable differences], the tendency was for the PLATO effect to be generally negative for lower ability students and positive for higher ability students" (ibid, p. 88).

ETS's most interesting finding involved the general reception of the program, as evidenced by surveys of instructor and student attitudes, which were taken after the system had a chance to prove its usefulness. About one out of ten people polled responded to the questionnaires.

On the whole, students were favorably impressed with PLATO, but felt it should be integrated into a course rather than be the sole method of instruction. They did not feel that PLATO was either "dehumanizing" or "boring," concerns often expressed about computerized instruction. Students who had used PLATO had more

favorable attitudes toward it than students who had not used it. In addition, over half of the students who had not used PLATO wanted to.

Instructor attitudes were also generally favorable; most teachers said they would probably use PLATO again. There was some disagreement as to whether PLATO was more effective with students of a particular ability level, and whether it had any effect on attendance. Many instructors felt they had spent either the same or more time with students in PLATO classes, and indicated that PLATO seemed to increase the amount of time spent on preparation--making PLATO less of a time saver than had been hoped.

Throughout this report, the ETS evaluators seemed to want to be as fair as possible to the project's participants. PLATO had not had noticeable effects on either attrition or achievement, two recurrent problems in community colleges that the originators hoped to influence positively. The ETS reports concludes its summary of attitudes toward PLATO with the following statement:

> A reasonable implication of these results appears to be that the general approach used in this implementation and demonstration should be continued. The various components of the system should be voluntary at the student level. More help sequences in the lessons and less stringent answer judging routines would be desirable. By and large, based on the judgements of instructors and students, the strengths appeared to significantly outweigh the weaknesses (ibid, p. 139).

PLATO continues to be used in the Chicago community college system, and is now at the University of Illinois at Chicago as well. It seems to have little effect on any campus as a whole: some instructors have their students take advantage of it, and some write lessons for it, but not according to any particular design. In sum, PLATO has neither solved the major instructional problems faced by these schools, nor has it contributed any of its own.

TICCIT was devised, implemented, and evaluated in Virginia and Arizona while PLATO was being installed and evaluated in Illinois. The systems were similar in that both were intended to meet the needs of community college students in introductory courses, but they differed in instructional design and function in the

curriculum: while PLATO was to be used as a supplement, TICCIT courseware was intended to serve as an alternative to traditional classroom instruction, and the instructional programs were written according to rigid specifications.

The TICCIT project had several specific aims. The nonprofit MITRE Corporation, which initiated it, wanted to develop a computer-assisted instructional program with commercial potential. MITRE estimated that community college students spend 20 percent of their time in remedial mathematics and English classes, and as enrollment in these schools was expected to continue to climb (and has), there seemed a strong possibility that this was a viable market. MITRE also wanted to use available hardware and a local computer, rather than the long-distance network arrangement PLATO has.

The instructional sequences were under student control and completely for classroom instruction, freeing teachers, it was hoped, for work with individual students. For hardware, MITRE chose minicomputers attached to keyboard terminals and color television sets. They selected two growing, demographically representative urban community colleges, both of which gladly participated; one outside of Washington, D.C., the other in Phoenix. The Institute for Computer Use in Education (ICUE) at Brigham Young University designed the instructional software. The TICCIT project, too, received an evaluation from ETS, and the discussion here is based on their report (Alderman, 1978).

It is in the design, purpose, and manner of production for the courseware that PLATO and TICCIT differed most markedly. ICUE believed that learning should be student rather than instructor driven and that instructional design is independent of subject matter. A systems approach to courseware production was followed; six-person teams composed of various specialists were to break the content for the courses into units, lessons, and segments. This last was to consist of a rule, example, and practice; students would choose the sequence of segments and difficulty level, and request help from the machine when necessary. Students were

to be guided through each course by means of "maps," or learning hierarchies that followed a Gagnéian model.

This structure proved too rigid: the teams had difficulty staying within it and making their deadlines. Despite these problems, TICCIT courseware was much more carefully designed and developed than the PLATO lessons.

For the two years of its demonstration phase (1975--77), when the ETS evaluation took place, TICCIT involved 5,000 students in more than 200 sections of the five different courses. ETS's most startling finding was the effect TICCIT had on course completion rates, which was overwhelmingly negative. This tendency was most pronounced in the mathematics sections, when TICCIT was to serve as a full substitute for classroom instruction. The average course completion rate for TICCIT sections was 16 percent compared to 50 percent for non-TICCIT sections. In the English course, where the instructors selected parts of TICCIT to use, course completion rates were not so negative.

ETS found these dropout rates similar to those of other self-paced courses at both schools, which suggests that community colleges are not an appropriate setting for self-paced instruction. The heterogeneity of these student bodies, and particularly their wide age range, make it difficult to anticipate students' needs. Those with stronger initial skills were more likely to complete a course. Shifting control from teacher to student may not work here because self-paced programs risk losing students unable to manage their own instruction.

TICCIT's effect on student achievement was more positive--TICCIT students average scores were 10 percent higher on the algebra posttests than those of non-TICCIT students. The English composition scores were not so dramatic. ETS felt these achievement gains were not justified by the high attrition rates.

One surprising result led the ETS evaluators to make other generalizations about CAI. The mainline English fundamentals course had a positive enough achievement score to balance the negative completion effect. Students in these sections

took all their instruction through TICCIT. But, instructors supplemented this with small group discussions and written assignments, a combination that seems to have worked well:

> Finding positive treatment effects on test performance in English surprised us. Prior studies of computer-assisted instruction, especially at the college level, suggest that this teaching method might benefit highly structured subject fields. But perhaps that structure also acts as a deterrent to student progress in a self-paced system. A subject less well defined might be conducive to greater teacher participation and more realistic expectations of computer capabilities for teaching.
>
> Without a definite structure to the subject matter there is also opportunity for student choice and teacher direction. And the rigor of developing computer curricular materials would probably be beneficial in forcing specificity and structure on teaching ill-defined subjects. Perhaps we should pursue techniques like computer-assisted instruction for teaching in the humanities, social sciences and other similar fields with as much energy and excitement as usually devoted to disciplines known for their structure (ibid, p. 298-99).

In sum, the evaluators concluded that CAI seems not to offer support sufficient for the needs of poorly prepared students, but may provide a cost-effective support, and perhaps enhancement, for students with stronger abilities.

The English course that showed positive achievement results also scored well on the student attitude assessment. The other English courses, a combination of regular classroom instruction and CAI, received negative student assessments. This mixed approach was confusing; it was like taking one course from two different instructors. There is an interesting similarity here to PLATO, in which CAI was offered on an inconsistent basis. CAI may work best if used in an organized fashion, teaching those aspects of a course or subject to which it is well suited, but this needs to be determined beforehand.

Student attitudes toward the TICCIT math course were less favorable than student attitudes toward the lecture classes, which the ETS evaluators attributed to the students' perception that they did not receive enough individual assistance: the math instructors felt they were actually devoting more time to helping

individual students in TICCIT courses. Perhaps CAI used as a complete substitute for classroom instruction generates a greater demand for individual attention, because students do not see an instructor regularly.

The TICCIT system was sold to a commercial developer while continuing to be used and promoted by its originators (Bunderson, 1981). In 1976, CERL licensed Control Data Corporation to develop PLATO commercially. Neither system, however, has been adopted on a widespread basis. The microcomputer, with its sophisticated exterior design, makes both PLATO and TICCIT installations look like relics of an earlier age.

Both were interesting projects, perhaps more useful for what they have to teach about CBE than for what they accomplished. Both projects provide ample evidence that computerized instruction should be integrated into classroom instruction rather than serve as a substitute for it. Neither project saved instructor time, nor proved useful for poorly prepared students. As might be expected, students initially stronger performed better.

A Learning Model for Higher Education

While both TICCIT and PLATO were in the midst of their demonstration phases, Rockart and Scott Morton, professors at M.I.T.'s Sloan School of Management, prepared their report for the Carnegie Commission--Computers and the Learning Process in Higher Education. This concentrated on one aspect of the Carnegie-sponsored Levien report published a few years earlier; subtitled Instructional Uses of the Computer in Higher Education, it had looked at the rapid growth of computers not only as tools for research, but as something to learn with, learn about, and to administer learning. Rockart and Scott Morton narrowed their focus, as their title implies. Their report provides a conceptual framework for the integration of various technologies into the learning process in higher education. As they say in their introduction:

> This report focuses almost exclusively on the teaching-learning interaction, as we contend that this is at the center of a university's purpose and is the area in which the least innovation has taken place to date. In addition, it is an area in which there exists considerable potential (Rockart and Scott Morton, 1975, p. 4).

They begin by offering a model of the learning process on which they based their analysis, asserting that insufficient formal use is made of learning theory in higher education:

> Every use of <u>any</u> type of methodology in education is based, explicitly or implicitly, on a model of the learning process. Until each of us involved in the process of education clarifies, or at least states, his own model of the learning process, little viable, constructive discussion of the place of <u>any</u> technology in higher education is possible (ibid, pp. 5-6).

Thus, they devise a model of the learning process into which they fit various learning aids--lecture and textbook, laboratory work and overhead transparencies, television and the computer. They argue that: "Any given technology is appropriate for certain types of material and quite inappropriate for others--being clear on where computer technology fits the material contributes to an understanding of where its ultimate impact will be" (ibid, p. 2). In the past, they continue, studies of computer-based learning focused on only one question, that of cost effectiveness. They then pose two other questions, which they consider to be just as significant: (1) In what specific ways will the computer affect the learning process in higher education, and (2) what selection criteria should one use when choosing computer-based materials?

In their chapter on the learning process, Rockart and Scott Morton differentiate between stimulus-response (S-R) and cognitive theories and delineate their practical consequences. CAI, because most early experiments were based on the teaching machine model, followed the S-R theory of learning and resulted in many computerized drill-and-practice exercises. Rockart and Scott Morton also mention a third school of learning theory, that of developmental psychology,

which relates learning to physiological process, particularly in children, and is based on observational rather than experimental techniques.

Rockart and Scott Morton maintain that these three theories are of limited usefulness in designing university instruction, and offer their own model, based on the stages of the learning process and the characteristics of the material to be learned. In devising their model, they refer to David Kolb's experiential learning model, in which "learning is conceived of as a four-stage cycle which translates experience into new concepts" (ibid, p. 19).

The first stage of the Rockart and Scott Morton "general learning model" is the "acquisition of basic components" of new knowledge. The second stage is the embedding of new knowledge through practice and "pondering." In the third stage, new knowledge is integrated or incorporated into former conceptual structures, leading to the formation of new "mental models of the universe." The final stage is the testing of new conceptual structures, a stage which, they say, breaks down in formal, university education because there are few pedagogical mechanisms by which the student "can test the implications of his new understanding" (ibid, pp. 20-21).

The material to be learned is the second major variable in their model. Of the different ways material can be categorized, they pick four: (1) facts, or definitions and other basic information, (2) skills, which include procedures or rules and their applications, (3) established concepts, or theories and hypotheses that are widely accepted--and no longer of interest to current researchers, and (4) frontier concepts, recent developments and those issues that have not been resolved. Individual characteristics of the learner and the teacher are also critical to learning, but are too complex to be integrated usefully into their model. Characteristics of the environment are also significant, but their interaction with the other variables is also complex. Rockart and Scott Morton concentrated on stages of learning and characteristics of the material because they are stable and "relatively impervious to the impact of technology" (ibid, p. 19).

To test the usefulness of their construct, Rockard and Scott Morton surveyed their colleagues to see which categories were emphasized in the social sciences, two "disciplines" (mathematics and economics), and the professions. They argue that undergraduates in the disciplines and the professions concentrate on the acquisition of facts and skills, while students in the social sciences spend more time on established concepts. Ph.D. students in the social sciences and the professions are mainly concerned with frontier concepts, and those in the disciplines with established concepts. Master's degree students fell, with varying emphases, in the middle.

The basic learning model has two variables, each with four divisions. Together, these produce 16 cells, as shown in the attached figure. Rockart and Scott Morton discuss methods of assisting the learning process, which they divide into three ~~traditional~~ categories: traditional, newer, and computer. "Traditional" methods include the lecture, textbooks, case studies, discussions, written assignments, and laboratory experiments. "Newer noncomputer methods" include audiovisual presentations and programmed instruction. The computer methods mentioned are the standard programmed instruction and the more sophisticated simulations, games, and inquiry modes. Unfortunately, they make no attempt to assign these various methods to positions or cells on their model, except by implication later.

In matching technology to learning, Rockart and Scott Morton rename these methods of assisting the learning process "learning mechanisms" and define their attributes, none of which fit neatly with a particular mechanism. These attributes they classify as content related (degree of structure, "richness," flexibility), user-related (adjusting to individual needs, ease of use), communication-related (amount of sensory and emotional impact), and economic (cost per and decentralized availability). They again polled the M.I.T. faculty and tried to assign the importance of each attribute to a particular cell in their learning

model. Their attempt to break all these things up into such neat categories was not completely successful, but they do eventually arrive at some useful generalizations.

First, the specific attributes (e.g., structure, ease of use, impact, cost) are organized into another set of groupings: (I) cost effectiveness, (II) adaptability, (III) feedback, (IV) learner control, (V) data manipulation and emulation of the real world, and (VI) enhancement. These they assign to groups of cells in their learning model (see figure).

The second grouping of attributes is then interrelated with their position on the learning model and their various supporting aids to learning.* At this point, the implications for matching technology to learning become clearer. A summary of their assertions follows.

I. Cost Effectiveness (including ease of use, cost, availability): The faculty poll rated these attributes as supporting mainly the acquisition of facts and skills. The effective aids to learning are textbooks, lectures, and tutorials. Although it has often been used to serve this function, the computer is not considered effective here.

II. Adaptability (presenting structure or dealing with the lack of it, presenting new concepts, adjusting to individual needs): These were related by the faculty poll to the acquisition of both established and frontier concepts. The lecture and class discussion are the most versatile and effective aids to learning. Audiovisual aids are useful for presenting structure, but less flexible for adding new material or adjusting to individual needs. Computer-based learning is of limited usefulness.

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*Rockart and Scott Morton assign some learning aids to these various categories, but their reasoning is not always clear. Many of the learning mechanisms mentioned in this summary, I have assigned.

III. Feedback (originally defined as a communications-related attribute, this allows "the learner to know early whether he has understood the meaning of a fact, internalized a skill, or grasped a concept," ibid, p. 134): The poll rated this as useful to the embedding of facts, skills, and established concepts. Drill and practice, laboratory exercises, and programmed instruction are the related aids to learning. Computerized drill and practice is useful for providing immediate feedback, but is more expensive than workbooks or paper and pencil. Computerized laboratory simulations may become more cost effective than actual laboratory experience.

IV. Learner Control (presenting structure, providing clerical assistance, adjusting to individual needs): These attributes aid the integration of skills and established concepts. Rockart and Scott Morton claim that these have tended to be neglected areas in formal education, and that technological mechanisms "appear most effective for this state of the learning process" (ibid, p. 154). The "number crunching" capability of the computer enables CBE to provide clerical assistance, and its manipulative capacity aids learner control. Films present structure, but do not adjust to individual needs.

V. Real-world Emulation and Data Recall and Manipulation (telescoping time, providing a rich environment, fast access to data and models): These attributes enable the learner to test the facts, skills, and concepts learned, and to integrate frontier concepts. Like learner control, this is another neglected area, and one amenable to computer-based learning. Computer-based games and simulations and ready access to databases are good examples, only recently feasible.

VI. Enhancement (presenting structure, telescoping time, sensory and emotional impact): These were rated as of secondary importance in almost all cells. This group of attributes is most generally served by films, some laboratory

demonstrations, an unusually gifted lecturer, and the computer, particularly the graphics aspects of micros.

Two conclusions emerge from Rockart and Scott Morton's analysis: (1) most computer-based learning of the past, particularly CAI, represents a role for computers that is better served by less expensive mechanisms, particularly textbooks, pencil, and paper, (2) the computer can enable previously neglected aspects of the learning process to be addressed. The latter consideration seems particularly useful in higher education, especially professional schools, whose graduates enter the real world with little or no apprenticeship.

Related Studies

In an article about research on college teaching, James and Chen-Lin Kulik, of the Center for Research on Teaching and Learning at the University of Michigan, comment on findings pertinent to a discussion of computer-based learning. Many of their observations can also be construed to confirm aspects of the Rockart model.*

As the lecture has been the most frequently used method of college teaching, most studies have compared it with other approaches. As classroom discussion is probably the second most widely used method, many other studies have compared the two, and found that when the criterion of effectiveness is learning factual information, neither lecture nor discussion is more effective. However, when the objective is higher level cognitive tasks, such as problem-solving, class discussion is more effective.

Both of these observations fit well with the Rockart model. It categorizies the lecture and discussion as effective for the acquisition of concepts, for which factual information is an essential "building block." This relates to their

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*For simplicity's sake, only the first author's name will be used in discussing the model.

"adaptation" attribute. If embedding and integrating facts, skills, and concepts are regarded as higher level cognitive tasks, the Rockart model explains the Kuliks' observation about the effectiveness of classroom discussion--it aids feedback and learner control attributes. Though Rockart refers to problem-solving as an aid to learning rather than something to be learned, as the Kuliks do, it does involve cognitive tasks that fit in the middle of their model.

The Kuliks discuss other alternatives to the lecture--instructional media (mainly television), programmed instruction, and computer-based teaching. The first provides drama, but has no effect on achievement (like films, an enhancement attribute that makes little difference to learning). Neither programmed instruction nor computer-based teaching had significant effects on achievement, but both seem to reduce learning time. Though the PLATO and TICCIT projects offer conflicting evidence regarding CBE, programmed instruction fits into the Rockart model as an effective way to embed factual information, a confirmation of the Kulik observation.

One of the Kuliks' most interesting assertions is that individual study has a greater impact on success in college than does classroom instruction. They found some investigators claiming that lectures and discussions might be reduced or eliminated with little effect on student achievement. As the TICCIT experience demonstrated, the importance of the classroom may not so much be in the amount of "learning" that goes on as in the contact with others, the interchange between teacher and learner and among learners. Eliminating this aspect of instruction seems to cause high attrition rates, and thus makes less inevitable the spectre of learners isolated from their peers by taking individual instruction at terminals.

The Kulik article did find that studies confirmed the usefulness of Keller's Personalized System of Instruction (PSI): "Research has produced impressive evidence on the effectiveness of PSI as a total system....All reviewers have concluded that personalized instruction usually leads to higher levels of achievement

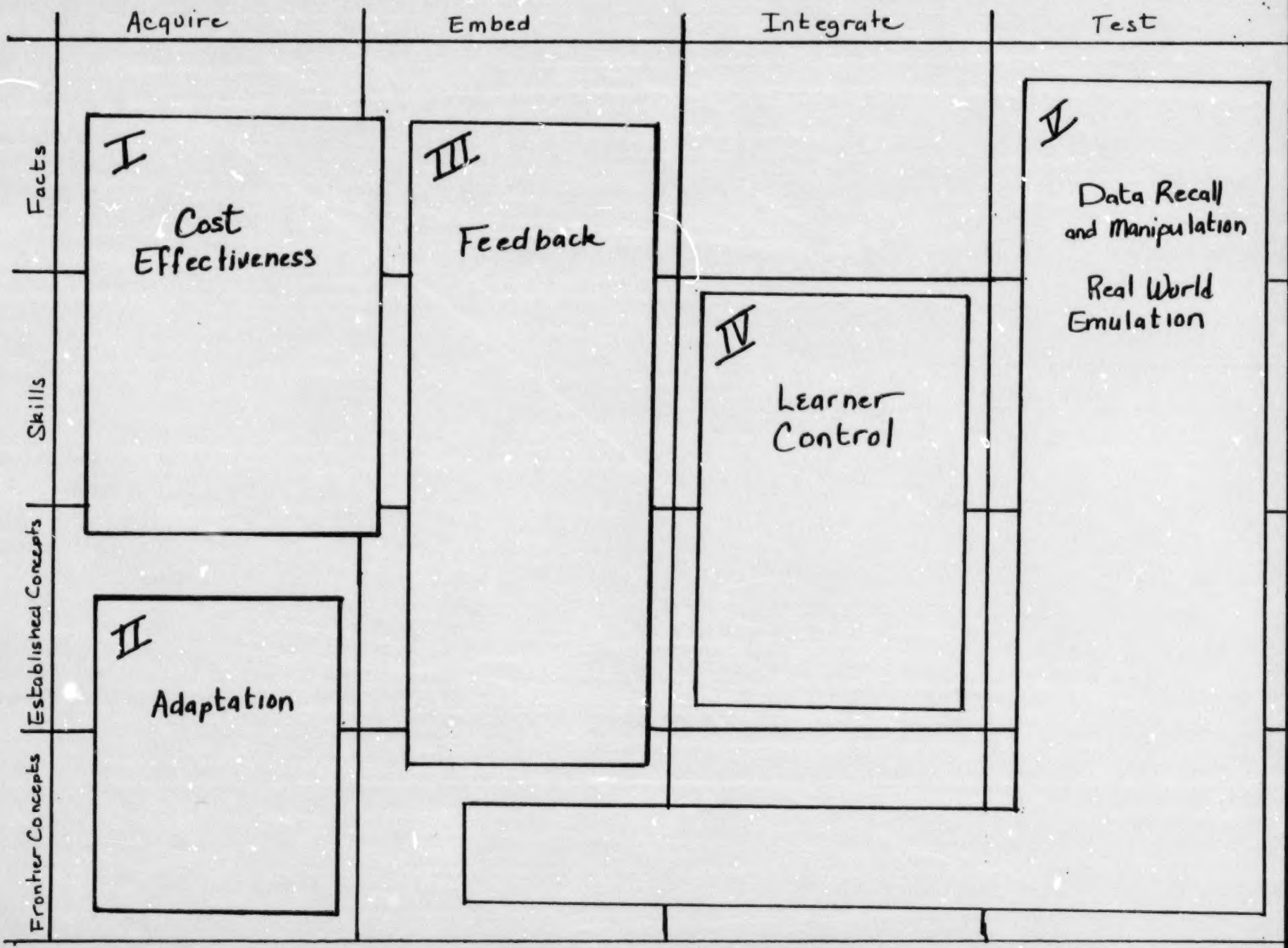
and more favorable student attitudes" (Kulik and Kulik, 1979, p. 79). As they describe PSI, it has five defining features: individually paced, mastery oriented, and student proctored, with printed study guides available, and some lectures to stimulate and motivate students. This finding has some interesting implications for computer-based education, and confirms another aspect of the Rockart model.

There are two large-scale remedial courses in operation at two Chicago universities, both based on PSI and computer-managed in whole or in part. One has been in operation for nearly ten years, the other four. One, in remedial mathematics, is individually paced, mastery oriented, and follows two standard workbooks (Goddard, 1982). It does not have student proctors or lectures. Like the TICCIT program, it has suffered from abnormally high attrition rates, confirming, perhaps, the need for personal contact--students in this course study the material from a text and then sign onto a terminal to be tested. There is little contact with instructors. The computer both generates test items and records a student's progress through the modules. The computer-managed aspect of this course has worked well, but only one out of eight students completes the first part of the course, which excludes the rest from pursuing any degree requiring mathematics.

The other course is in remedial chemistry (Freeman, 1982). In addition to being self-paced and mastery oriented, it does have student tutors and a printed study guide to supplement the text, but it does not include lectures. It is computer-managed: records are kept by computer and tests computer generated, but hand graded. In an analysis of students' progress through the course, Freeman found that half who register dropped out before making much headway. Again, as the ETS evaluation of TICCIT found, poorly prepared students do not handle self-pacing well and need more instructor support than that provided by tutors.

One of the problems with both of these courses is that they are at the acquisition of facts and skills stage of the Rockart model. Students take them because they did not learn enough math or chemistry in high school to take

Attribute Groupings by Stages in the Learning Process



Adapted from Rockart and Scott Morton, 1975

college-level courses. Computer-based instruction may be more effective at the embedding stage, where drill and practice is more significant than lecture. The remedial chemistry course is being revamped to include lectures, in the hope that this will motivate students to continue (Freeman, 1983).

Another problem with these courses might be that they have not followed all aspects of the Keller design--in both cases, sufficient contact with instructors. The Kuliks report that other studies of PSI have not found differential attrition rates between PSI and conventional courses (Kulik and Kulik, 1979, p. 79). Perhaps these studies included more instructor contact.

Two other observations from the Kulik article are pertinent to a discussion of computer-based learning. One concerns the efficacy of frequent quizzing; the other, the focus on classroom rather than individual study. The Rockart model construes feedback to be essential to embedding facts, skills, and concepts. The Kuliks report that immediate and frequent feedback has a significant and positive effect on achievement and that timing is more important than form (that is, whether or not it is given with "proctor interaction") (1979, pp. 86-87). This supports the notion that computer-based drill and practice aids the embedding of facts, skills, and concepts.

The Kuliks' assertion about the importance of individual study to achievement supports another stage of the Rockart model--the integration and testing phases. As Rockart and Scott Morton claim, this has been a neglected aspect of higher education (1975, p. 155). Individual study would rate high on learner control attributes; instructional projects that emulate the real world and allow manipulation of real data on an individual basis rank high on learner control. The computer supports learning at both stages with its ability to handle clerical and numerical chores, offer games and simulations, and provide access to numerous databases. Though this computer capability may benefit students in graduate and

professional schools more than the general undergraduates, it may ultimately enable computers to make a substantial contribution to instruction.

The Kuliks also prepared a report on computer-based college teaching using a "meta-analysis" technique (Kulik et al., 1980). They combed the literature for studies and chose 59 that took place in classrooms, contained quantitative measures, and were methodologically sound. A full third of the studies were of projects that provided only tutorial instruction and that replaced conventional teaching for a full semester of work. About 20 percent of the studies were of computer-managed (as opposed to computer-assisted) instruction. Only 15 percent involved simulations and only 10 percent, computer problem-solving. In other words, they tested applications that, according to the Rockart model, were likely to be ineffective.

However, their meta-analysis did determine that computer-based instruction has a positive effect on achievement, although not all the individual effects were statistically significant. In controlling for other variables, they found that in some cases the instructor rather than CBE might have been the cause. (Perhaps the teachers were being more effective because of the CBE study.) Their analysis also found that CBE has at best a small effect on the correlation between aptitude and achievement, and a similarly small effect on student attitudes toward subject matter. On the whole, CBE had no effect on course completion rates, but it did result in a substantial saving of instructional time. One should be cautious about some of these findings because many were based on very small samples. Of the 59 studies, 54 had usable achievement scores; but Kulik et al. had a low of seven and a high of 13 studies on which to base the other findings.

All of the studies on which Kulik et al. based their analysis were reported between 1967 and 1978. Presumably, none involved microcomputers or students familiar with computer games. They were all CAI application using mainframes or minicomputers, and lacking the sophisticated graphics and sound now available. Many

of these studies were conducted while enthusiasts were still claiming that computers could "serve as infinitely patient tutors, scrupulous examiners, and tireless schedulers of instruction." Critics were calling computers "expensive gadgets" that would increase the cost of instruction without improving its quality while forcing all learners into the same mold" (ibid, p. 525).

Neither vision has become a reality, and the Rockart model suggests why: the tutorial CAI mode has not proved to be effective for presenting new material and is more expensive than other, more efficacious modes. If the latter situation were to change, there might be some cause for concern. But as the TICCIT experience demonstrated, students rebel at classrooms without instructors, and many simply refuse to learn. Another of the critics' concerns may still have some validity: that "computer requirements would ultimately affect the choice of instructional content" encouraging teachers "to teach only those things that could be taught easily by machine" (ibid, p. 526). If microcomputers become ubiquitous, and process words and numbers for us at home as well as at work, the need to teach many basic skills--such as computation and spelling--may become obsolete. There is no need to use a computer to teach skills that its presence has made unnecessary. Teaching to the test is not a new phenomenon, and in the meantime we have a generation of college students wanting technical jobs but without the computational skills that enable them to take the prerequisite courses. Human imperfectability may again save us from the ill consequences of our technology.

Conclusions

All indications are that extensive use of computer-based instruction will become a reality in postsecondary education within the next decade. Traditional academe and community colleges are being pushed into it from both sides. Microcomputers are being rapidly incorporated into elementary and high school education, and into the way this generation of young students amuses itself, as well as how it will earn a living later.

The world of work--where students of both sexes can expect to spend their lives--will demand at least some computer competence in almost all jobs. Ten years ago, when the nation's attention was on the war in Vietnam, few of us could have foreseen the extent to which technology devised to fight that war would invade our homes. But it has, and the prospect of that development is no longer frightening.

Many commentators on the subject have compared the advent of the computer to the invention of moveable type. However, mass-produced books were a possibility two hundred years before they became a reality (Johnson, 1981, p. 2). Gutenberg's invention was introduced into a world still largely illiterate. The printing press made literacy not only a possibility, but a necessity. The computer is forcing a similar change in how we communicate and store information, but at a much faster pace.

To borrow another analogy, Henry Ford introduced the automobile to a society that had not considered how to use one, and then produced them so cheaply that an entire nation suddenly discovered that it could not function without them (Luehrmann, 1980). The Pierce report also made numerous comparisons between the car and the computer. When first invented, the car required expertise in knowing how to handle it. Now, all kinds of people who don't know a clutch from an anxiety attack can acquire any make or model car with a small piece of plastic and drive it across the country.

The Pierce report also conveyed some interesting notions about ways in which computers could be incorporated into the learning process:

> Computing is a new resource in learning. It enables the student or the scholar to deal with realistic problems rather than oversimplified models. By lessening the time spent in the drudgery of problem solving and in the analysis of data, it frees time for thought and insight. Partly, it enables the student to do old things more easily, but more important, it enables him to do things he otherwise could not. Computing increases the quality and scope of education (PSAC, 1967, p. 1).

Three developments seem inevitable. Graduate and professional schools, including institutes of technology, are already recognizing the extent to which

computing affects what they are preparing students to do. Some have announced plans to incorporate the computer into the curriculum to such an extent that each student will be required to have one. Within the last year, schools of engineering have started courses on computer-aided design and manufacturing. Graduate students in the social sciences have long needed to be familiar with computerized statistical packages in order to do research. Business students need not only be able to do time series analysis, but handle computer-based spreadsheeting, and investment analysis. Agriculture has not only been automated, but is becoming computerized as well.

In undergraduate instruction, computers are taking their place among other instructional resources, now as a super calculator and, with graphics, an electronic blackboard. The word processor is a super typewriter, and may mean that once again neatness, correct spelling, and absence of "typo" errors will be required in student papers. Software packages and letter-quality printers make this possible. Eventually, micros may become a super laboratory or a mini-library, offering personal databases and bibliographic services (Johnson, 1981).

There are at present several "cottage industry" CBE applications at colleges across the country (Brown, 1981). Among these are attempts to seduce technical students into studying sociology by constructing a course around access to the National Opinion Research Center's General Social Survey, enabling them to manipulate this vast store of data through statistical software packages. Another school's classics department offers a sophisticated course in technical terminology, providing computer-based exercises in combining Greek and Latin roots with various prefixes and suffixes. Students can create hypothetical words or match Greek and Latin terms with English synonyms and antonyms. A simpler, but highly efficient, system devised by a geology professor programmed old exams into a computer network. Students had previously formed long lines at a paper-based file of questions. Now they can practice for tests at any one of many terminals located all over campus.

Applications like these will continue to grow as departments acquire their own computers and as students come in increasing numbers to campus with micros instead of typewriters. Publishers are capitalizing on the demand for courseware by offering study disks and computerized practice sets to students and computerized examination systems to their instructors.

The third development may be further off. What PLATO and TICCIT attempted to do would have served an important instructional function had they been more successful. There are yet large numbers of students taking remedial courses in mathematics, the sciences, and English, which often drain a department's resources and frustrate its faculty. These courses should eventually be amenable to computer management, although probably still with a high development cost. Possibly publishers or hardware manufacturers will be able to produce programs for these courses of sufficiently wide appeal to spread the cost enough to make them profitable. As aptitude and achievement tests, as well as smaller-scale reading and other proficiency tests, are produced by a few, large testing services, perhaps remedial courses will be marketed in similar fashion. A department or school could buy a modular testing program, and provide their own instructional services to personalize it.

The future as indicated by these projects is exciting, and certainly more varied and challenging than that proposed by the promoters of CAI a generation ago. The computer is a tool, perhaps the most versatile and useful tool humankind has yet devised. Though it probably will be responsible for a social revolution comparable to that of moveable type, its impact on postsecondary education will seem less a revolution than a natural development. Schools are in the midst of this process, needing guidelines and models to follow, as well as the sceptic's caution and the enthusiast's vision.

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